

# Forward Neutron Production at MIPP Experiment

Answers for questions and comments

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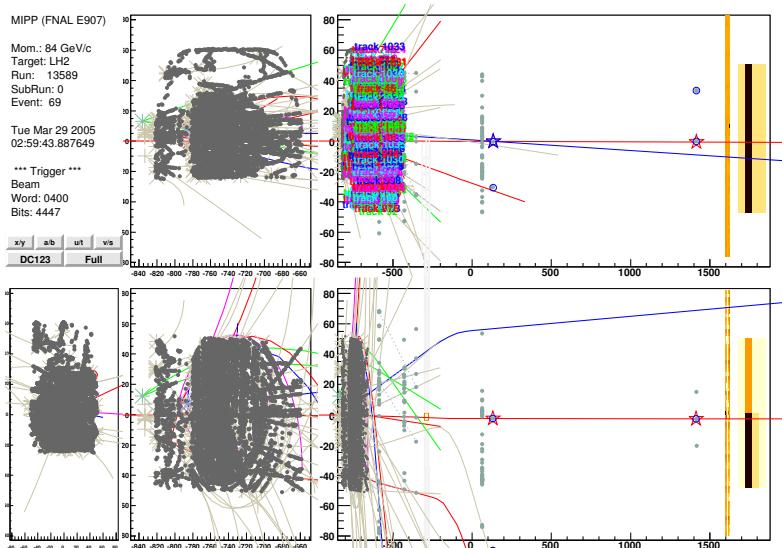
MIPP software/analysis meeting

February 2, 2010

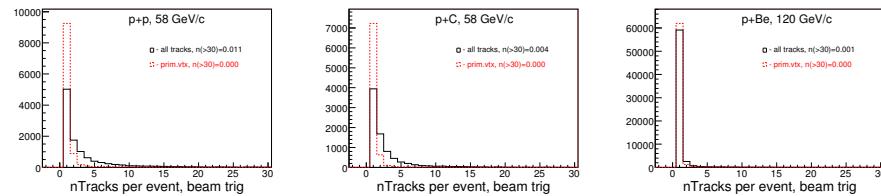
## Event selection: drop an event if $N_{trks} > 30$ tracks

Jon, Raja: Why you use this cut?

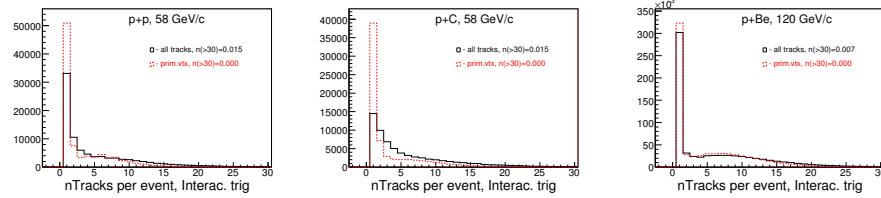
A: Some events are not useful for the neutron analysis. An example shown below:  $N_{trks}=224$ . (Run: 13589 Event: 69 Tgt: LH2 Momentum: 84 GeV/c)



What is a fraction of such events in the beam trigger?



A: This cut drops 0.011 events in beam trigger.  
Interaction triggers?



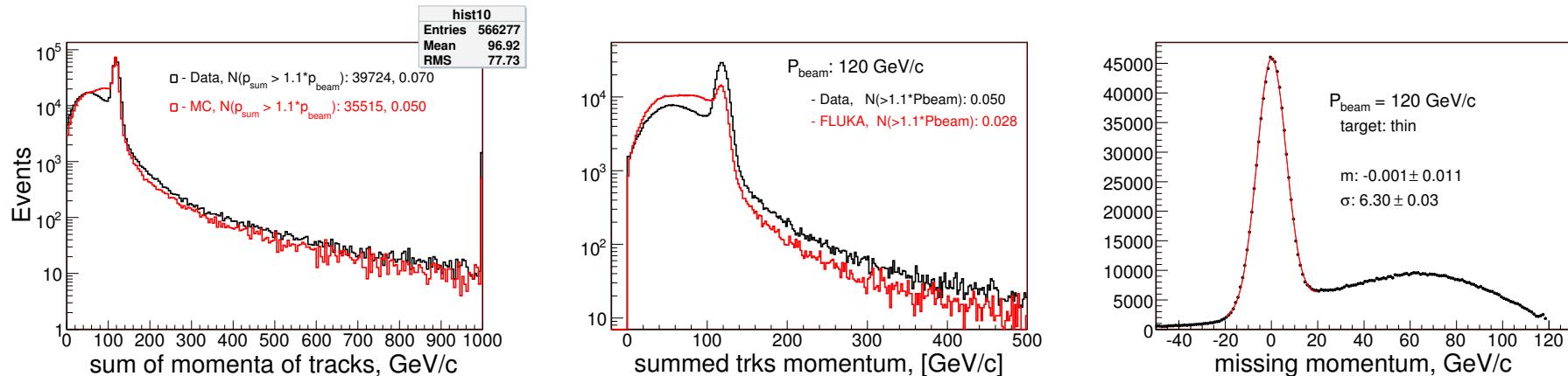
A: number of events when  $N_{trks} > 30$  all tracks: 0.015, 0.015 and 0.007, respectively. Events with  $N_{trks} > 30$  tracks in prim vertex: 0, 0 , 0, respectively.

This effect do not exist in MC

## Event selection: about $P_{sum} < 1.1P_{beam}$ cut

Raja: Factor 1.1 might be too tight. You might drop neutron events. Better to use something which will represents  $3\sigma$

software version: on left - pass4c, on middle and right - pass4f



A: Used cut value is  $1.1 \cdot 120 = 132 \text{ GeV}$ . Suggested value is  $\frac{3\sigma + P_{beam}}{P_{beam}} * P_{beam} = \frac{3 \times 7 + 120}{120} \times 120 = 1.175 \times 120 = 141 \text{ GeV}$ .

A: There is  $p_n > p_{min}$  threshold for neutrons; for this case  $p_{min}=20 \text{ GeV}$ . If neutron momentum  $p_n = p_{min}$ , then highest allowed  $P_{sum}$  value would be:  $120 - 20 = 100 \text{ GeV}/c$ . It is far away from 132 GeV. Thus, we loose nothing.

# Event and beam track selection cuts and rates

Jon: show same thing for MC.

A: MC numbers are in blue.

Cut name	N(58-H <sub>2</sub> )	R(58-H <sub>2</sub> )	N(58-Tt)	R(58-Tt)	N(120-Tt)	R(120-Tt)
Total events	802616		1667211		2615429	
nTrks $\leq$ 30	772373	0.962(0.998)	1543447	0.926(0.992)	2518598	0.963(0.998)
Calo status	772373	1.000(1.000)	1543447	1.000(1.000)	2518592	1.000(1.000)
Is beam trk?	745447	0.965(0.999)	1477568	0.957(1.000)	2470960	0.981(0.999)
Single beam trk	480130	0.644(n/a)	869439	0.558(n/a)	2011903	0.814(n/a)
nCrossing < 5	386237	0.804(n/a)	685526	0.788(n/a)	1674480	0.832(n/a)
radius-1<2.0cm	300063	0.777(0.957)	670633	0.978(0.999)	1618680	0.967(0.915)
radius-2<2.0cm			653655	0.975	1618680	1.000
track time	291234	0.971(0.999)	646536	0.989(0.999)	1610870	0.995(0.999)
trk divergence	290707	0.998(0.620)	645172	0.998(0.737)	1610784	1.000(0.999)
P <sub>sum</sub> <1.1P <sub>beam</sub>	275275	0.947(0.974)	602133	0.933(0.971)	1509270	0.937(0.968)
Overall rate		0.343(0.575)		0.361(0.708)		0.577(0.881)
Proton fraction	92414	0.336(1.000)	246413	0.409(1.000)	1499105	0.993(1.000)

## Incident proton sample sizes

target	$p_{beam}$	prescaler bit	direct scalers	ratio
$H_2$	20*	2215467	2063857	1.07
Empty Cryo	20*	397364	376001	1.06
$H_2$	58	17156645	16572320	1.03
Empty Cryo	58	2877699	2740163	1.05
Beryllium	58	2207422	2220883	0.99
Carbon	58	8751838	8603366	1.02
Bismuth	58	17164512	16274597	1.05
Uranium	58	32643688	30770547	1.06
Empty thin	58	12397130	11706104	1.06
$H_2$	84	31372847	28896245	1.09
Empty Cryo	84	10962656	9053908	1.21
Beryllium	120	19864149		0.08
Carbon	120	5542062		0.07
Bismuth	120	21559032		0.08

Raja: Why 84 GeV/c empty-Cryo difference is high?

A: No idea.

Jon: Assigning 10% uncertainty looks too high.

A: We will consider it.

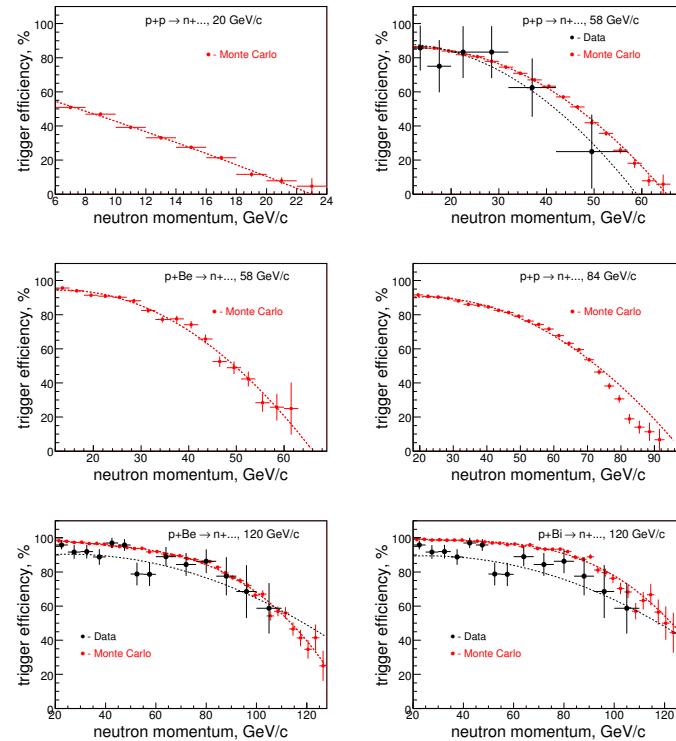
# Trigger efficiency

Jon: How errors were calculated?

A:  $\epsilon = \frac{\text{passed}}{\text{passed}+\text{failed}}$ , the denominator and numerator are correlated, then

$$\delta\epsilon = \frac{\sqrt{\sigma_{\text{pass}}^2(1-\epsilon)^2 + \sigma_{\text{fail}}^2\epsilon^2}}{\text{passed}+\text{failed}}$$

tgt, $p_b$	$N_n$	$\epsilon_{\text{trig}}(\text{data})$	$\epsilon_{\text{mc1}}$	$\epsilon_{\text{mc2}}$	$\epsilon_{\text{trig}}^{\text{avr}}$	$\text{syst}$	$M_{\text{mc}}^{\text{dat}}$
H <sub>2</sub> ,20	19	0.53±0.12	0.38 0.39		0.46	0.10	2.0 2.5
H <sub>2</sub> ,58	43	0.67±0.07	0.72 0.74		0.71	0.10	4.9 4.6
Be, 58	3	1.00±?	0.83 0.82		0.82	0.10	n/a 5.9
C, 58	5	0.80±0.18	0.85 0.84		0.84	0.10	n/a 6.6
Bi, 58	9	0.67±0.16	0.91 0.91		0.845	0.10	n/a 9.8
U, 58	40	0.78±0.07	0.92 0.91		0.845	0.10	5.3 10.0
H <sub>2</sub> ,84	137	0.66±0.04	0.82 0.80		0.73	0.10	
Be, 120	235	0.85±0.03	0.92 0.92		0.885	0.07	7.1 8.2
C, 120	129	0.88±0.03	0.93 0.93		0.905	0.05	7.7 9.3
Bi, 120	193	0.77±0.03	0.96 0.97		0.87	0.10	8.6 14.2



How it was applied to data?

The momentum dependence follows according to Monte Carlo prediction (red dashed curve).

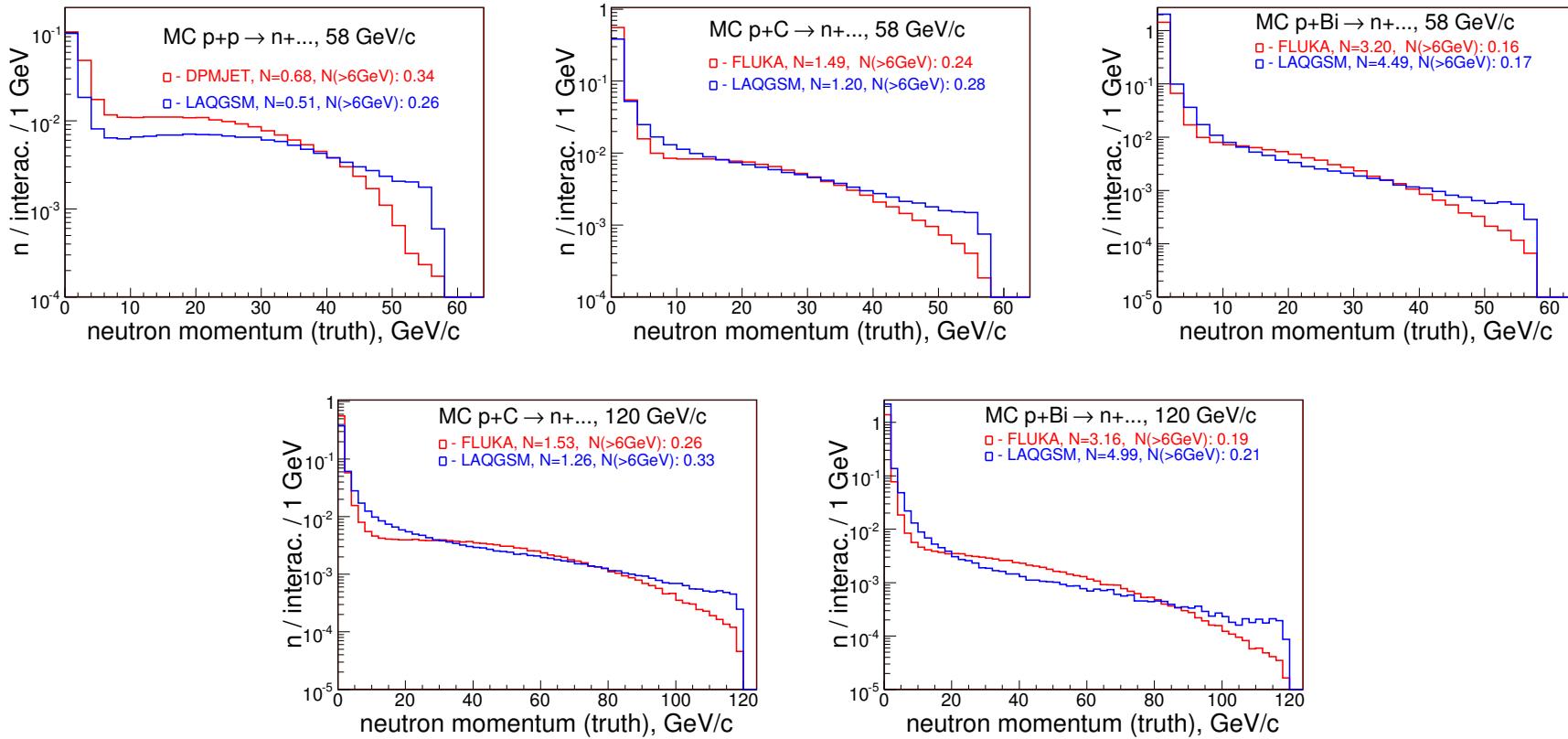
The level of each predicted curve was adjusted.

For an example, Bi-58 efficiency in each bin has been multiplied by factor 0.845/0.91

## MC neutron spectrum

Raja: It is interesting to see the full spectrum.

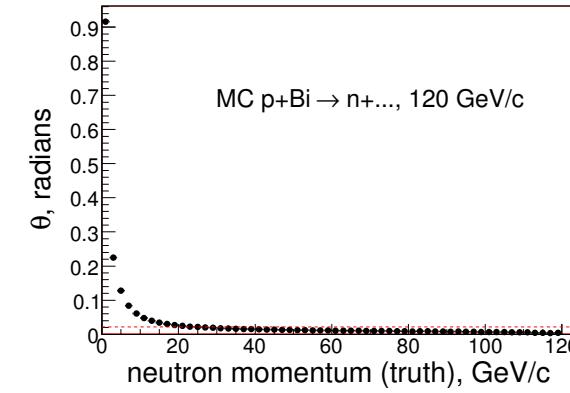
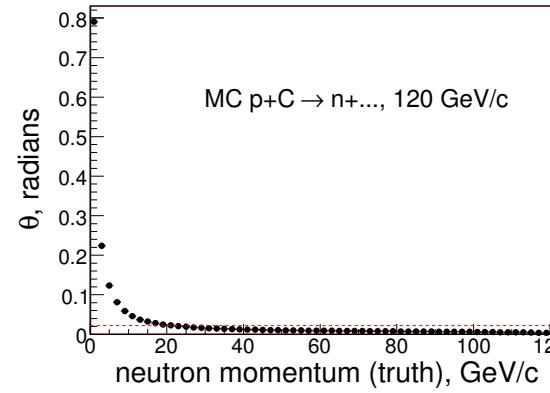
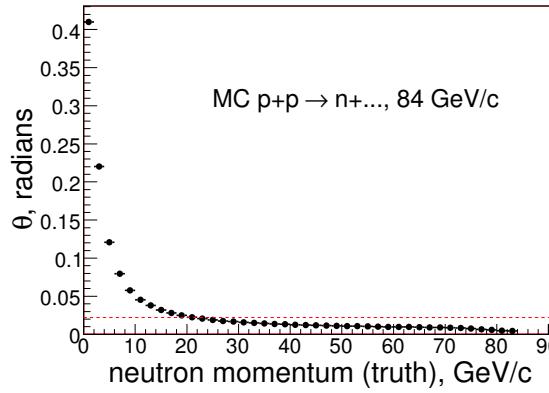
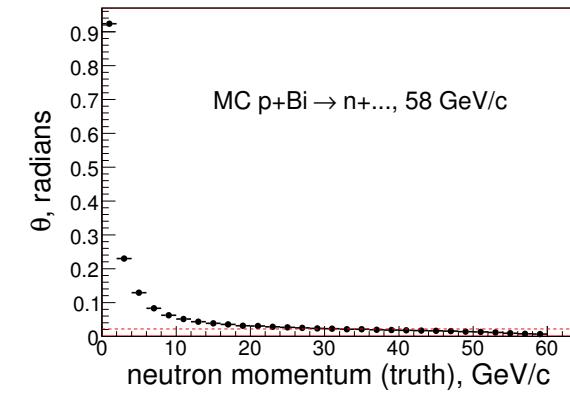
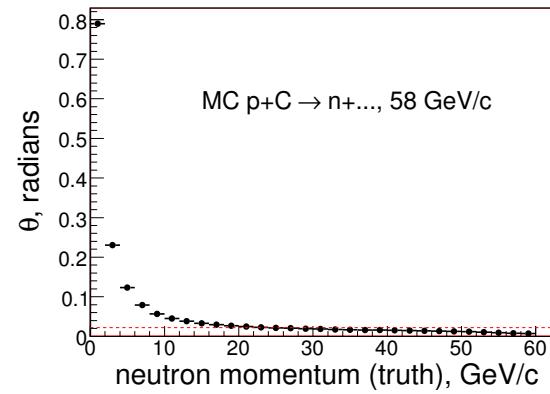
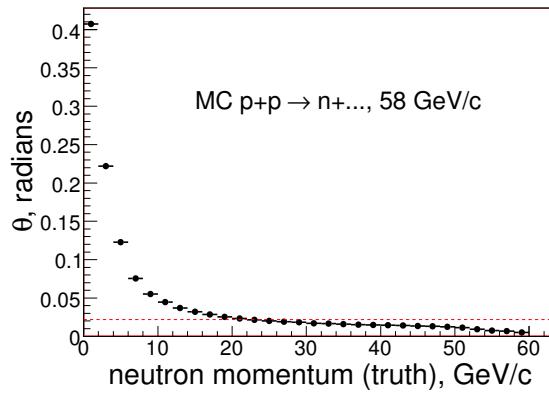
A: The neutron spectra and production rates per single p+A interaction with  $p_n > 100$  MeV/c threshold.



Observations: a)heavier target atomic weight causes to lower the fraction of energetic neutrons to be generated and  
 b)LAQGSM spectra looks harder than FLUKA/DPMJET.

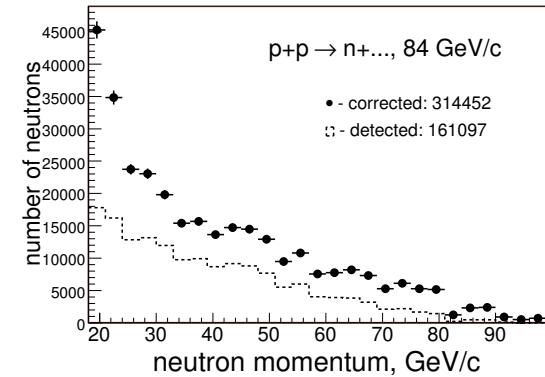
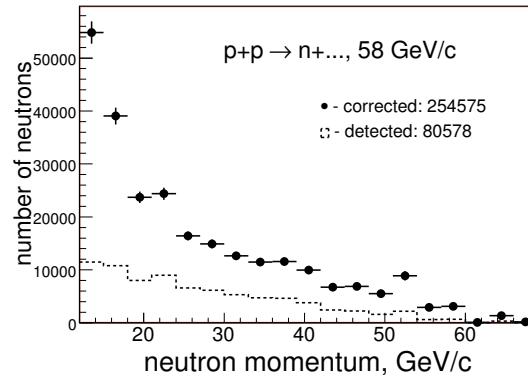
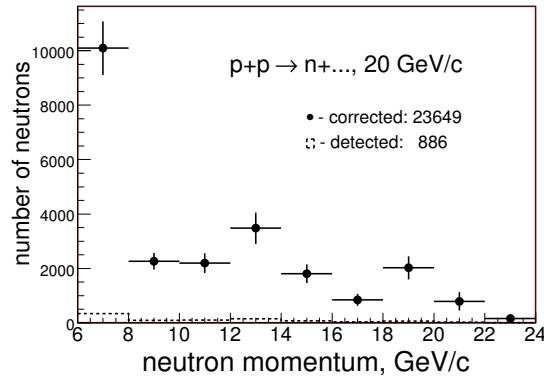
## MC neutron angle - momentum correlation

$$\sin\theta = \frac{p_T}{p_{tot}}$$



# Neutron spectra from p+p interactions

Jon, Raja: How errors were calculated for each bin?



A: The number of neutrons for given bin  $i$  was calculated as:  $n_i = \sum w_i$ , where  $w_i$  is an event weight, which is equal to the proton interaction prescaler, might vary on run-by-run basis.

The statistical error calculation is based on the size of neutron candidates:  $\delta n_i = \sqrt{k_i} \times \frac{N_i}{n_i}$ , where  $k_i$  is the number of candidates ( $w=1$ ) prior the target-out subtraction, factor  $\frac{N_i}{n_i}$  is to scale-up to the corrected sample size.

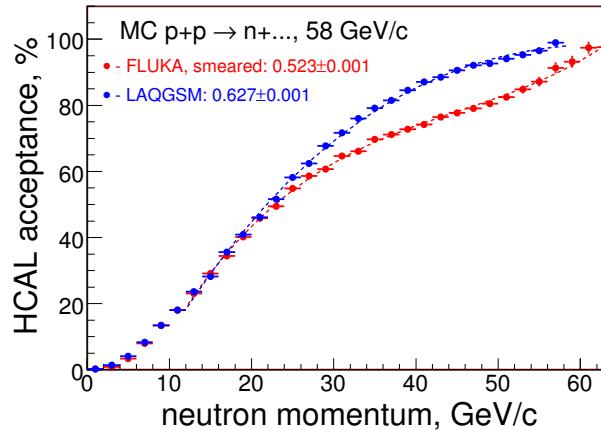
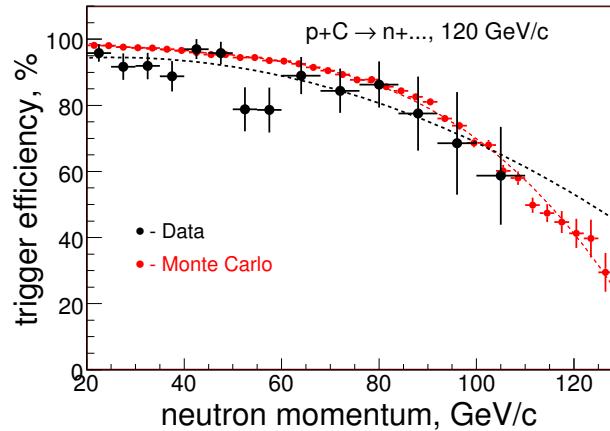
## systematic uncertainty of the trigger efficiency

$$N_n(p_n > p_{min}) = \frac{n_n(t-in) - n_n(t-out) - n_n(backgr)}{\epsilon_{trig} \times \epsilon_{hcal} \times \epsilon_{cuts}} \pm [0.10 \times \Delta N_{trig}]$$

Raja: Why not vary  $\epsilon_{trig}$  itself?

$$N_n(p_n > p_{min}) = \frac{n_n(t-in) - n_n(t-out) - n_n(backgr)}{[\epsilon_{trig} \pm \delta\epsilon] \times \epsilon_{hcal} \times \epsilon_{cuts}}$$

A: Because it will not work for cases when  $\epsilon_{trig}$  is close 1.0 - no room for +0.1, see left plot.



A: Same story if we would like vary  $\epsilon_{hcal}$  - $\delta\epsilon$  (right plot). For an example, after applying  $\epsilon_{hcal}-0.3$  for  $p_n=12$  GeV/c the resulting acceptance would be negative. One more things: the uncertainty will exceed the acceptance correction value itself.

## Other questions and comments

Raja: Comparison with existing data

A: Will do

Raja: Invariant cross section

A: Under discussions

Durga: Bi-120 vs Bi-58 GeV trend makes sense?

A: Within  $1\ \sigma$  uncertainty one might conclude that there are no trend there.

Durga: It would be good to estimate the acceptance uncertainty by varying  $p_T$  of neutron by  $\pm 10\%$ . Same approach as in NA-49.

A: Will do